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RESEARCH ARTICLE

Effect of potassium spraying and spraying dates on some growth, yield and chemical traits of tomato cv. Polonia

Basim Mohammed Abed[1], Idrees Hussein Mola Salih Al-Jaf[1], Ahmed Fatkhan Zabar Al-Dulaimy[1*] & Anmar Kamil Alalwani[2]

[1]Department of Horticulture and Landscape Gardening, University of Anbar, College of Agriculture, Ramadi 31001, Iraq
[2]Department of Biotechnology, University of Anbar, College of Science, Ramadi 31001, Iraq

*Correspondence email - ag.ahmed.fatkhan@uoanbar.edu.iq

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Abstract

This study was performed during the 2022 cropping season in the experimental fields of the Horticulture Department, College of Agriculture, University of Anbar, to examine the effects of foliar potassium (K) concentrations and application schedules on tomato growth, yield and quality of fruit. Tomato saplings (Polonia cv.) were transplanted to the open area and the experiment was structured in a randomized complete block design (RCBD) with three replications. Two factors were explored: five K doses (0, 1000, 2000, 3000 and 4000 mg L^{-1}) and three application timelines (10, 21 and 42 days post-transplanting). The research assumes that foliar application of potassium at advanced concentrations and proper spraying times can effectively improve vegetative growth, yield factors and chemical traits of tomato plants. This hypothesis handles a critical comprehension gap in insight the association between potassium supply and plant physiological reactions under the agro-ecological environments of Iraq. Furthermore, confirming or refusing this hypothesis has practical significance for green agriculture, as it supplies executable guidance for enhancing both yield and economic returns in tomato yield. The results revealed that the treatment K2 (2000 mg L^{-1}) significantly improved height of plant and leaf area, while K4 (4000 mg L^{-1}) enhanced dry weight, flowers number, yield of fruit and leaf potassium content. Spraying at S3 (42 days after replanting) significantly raised most traits of growth and yield. The interaction of potassium treatment and applying schedule disclosed that K4S3 and K2S3 treatments achieved the highest values for the studied traits. These findings highlight the originality and significance of the research, illustrating that a carefully enhanced potassium application strategy, combined with proper applying schedules, can immediately enhance tomato productivity and quality of fruit. generally, this study provides both scientific perceptions into nutrient–plant relations and practical guidance for enhancing farmers' yields and gainfulness in fresh market and managing tomato production systems.

Keywords: growth; potassium; spraying dates; tomato; yield

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most extensively cultivated vegetable crops across the world and in Iraq, as a result of its high nutritional, medicinal and market value. It is a self-pollinated, herbaceous plant associated with the Solanaceae family, with a paired chromosome number of 2n = 24. Tomato contain fundamental vitamins, comprising vitamin C and E, minerals like calcium and bioactive compounds such as carotenoids, lycopene and phenolics, which play a role in human health and improve market value (1). insight the physiological responses of tomato plants to nutrient management is necessary for optimizing production systems under changing agro-ecological conditions (2).

Global agriculture faces countless challenges, comprising prompt population growth, climate shifts, soil degradation and diminishing freshwater existence, all of which threaten food harmlessness. The Food and Agriculture Organization (FAO) schemes that agricultural productivity must augmentation by around 70 % above the next three decades to accomplish the growing requirement for food in terms of both quality and quantity. These stresses demand the adoption of long-lasting nutrient administration strategies that not only refine yield but also preserve natural resources and secure environmental long-term viability (3, 4).

K is a primary macronutrient required for tomato plant development and growth. It adjusts several physiological and biochemical calibrates, encompassing enzyme induction, photosynthesis, protein synthesis, osmotic refinement and secondary metabolite production (5). sufficient K supply optimizes vegetative growth, size of fruit, total soluble solids content, ascorbic acid quantity and fused yield, directly influencing both quality of production and economic returns. Potassium insufficiency, conversely, can lower growth of root, lateral branching and biomass amassing, thereby weakening plant efficiency and financial return (6).

Efficient nutrient exploitation strategies, like foliar spraying, availability direct nutrient provision to the plant, assuring rapid absorption and minimizing nutrient depletion to the environment (7). Foliar K application can diminish soil-related deficiencies, enhance plant water-use capability and improve the absorption of macro- and micronutrients (8, 9). Such techniques are especially important in zones with constrained soil fertility and water reachability, including the agro-ecological territories of Iraq, where optimizing input effectiveness can significantly affect farm-level economics.

For all nutrient boost strategies to be achievable, they must ensure not only environmental affability but also economic financial return. Refining potassium application can diminish input costs, rise marketable yield and strengthen fruit quality, thus offering substantial economic gains to growers (10). regarding industrial viewpoints, these strategies provide actionable guidance for farmers and investors seeking sustainable and profitable crop production, aligning with global patterns in precision agriculture and ustainable farming (11).

This study concentrates on evaluating the effects of foliar potassium application at changing concentrations and spraying timelines on vegetative growth of tomato, yield and chemical traits of fruit. The research assumption is that optimized foliar potassium application, applied at suitable concentrations and schedules, can significantly strengthen growth, components of yield and quality of fruit of tomato plants. Confirming or refusing this hypothesis addresses an essential knowledge gap in nutrient–plant interactions under the agro-ecological conditions of Iraq and has practical significance for enhancing productivity of crop, resource-use efficiency and financial gains in tomato production system.

Materials and Methods

This research was conducted during the 2022 planting season at the research field of the Department of Horticulture, College of Agriculture, University of Anbar, Ramadi, Anbar, Iraq. Tomato seeds of the Polonia variety were initially sown in cork trays. After seed germination and the emergence of true leaves, seedlings were transplanted to the field, where they were planted on terraces measuring 3 m in length. The distance between terraces was 0.81 m and the spacing between seedlings along each terrace was 40 cm. Each experimental unit consisted of 14 plants, covering an area of 5.40 m^2. Physical and chemical characteristics of the culture medium are shown in Table 1.

Treatments

The first factor consisted of five potassium sulfate (K_2SO_4) concentrations: 0, 1000, 2000, 3000 and 4000 mg L^{-1}, symbolized as K0, K1, K2, K3 and K4 (12).

The second factor was three foliar spraying dates corresponding to key growth stages:

1. Seedling stage (10 days after transplanting, with 4 true leaves S1)
2. Flowering stage (21 days after the first spraying S2)
3. Fruit-setting stage (42 days after the first spraying S3) (13).

Measured Traits

Plant height (cm): Measured at the end of the growing season from the soil surface to the apex of five randomly selected plants per experimental unit (14).

Leaf area (dm^2 $plant^{-1}$): Measured using an AN 100 device produced by England Science Instruments (citation - VK K). Measurements were taken from the fifth leaf of five randomly selected plants per experimental unit (15).

Dry weight of the vegetative system (g): Five plants per experimental unit were harvested at the end of the season, with roots and fruits removed. Samples were dried at 70 °C for 48 hrs and the average dry weight was calculated (16).

Total chlorophyll content (mg 100 g^{-1}): Estimated after the third spraying using a Shimadzu visible spectrophotometer (UV-1800 Double Beam, Shimadzu Corporation, Kyoto, Japan) at wavelengths of 645 and 663 nm. Total chlorophyll content was calculated (17).

Number of flower inflorescences (inflorescences $plant^{-1}$): Counted on five plants per experimental unit.

Fruit number (fruit $plant^{-1}$): The total fruit count per experimental unit was divided by the number of plants to obtain the average fruit number per plant.

Fruit weight (g): Calculated by dividing the total fruit yield per experimental unit (kg) by the total number of fruits, then converting to grams.

Plant yield (kg $plant^{-1}$): Total yield per experimental unit (kg) divided by the number of plants.

Leaf nitrogen and potassium content (%): Determined using the micro-Kjeldahl method (Labconco Corporation, USA) for nitrogen (18) and a flame photometer (Model AA-7000, Shimadzu Corporation, Japan) for K (19).

Statistical Analysis

The experimental data were subjected to analysis of variance (ANOVA) according to the RCBD with three replications. The least significant difference (LSD) test at the 0.05 probability level was used to compare treatment means (20). All statistical analyses were performed using Genstat statistical software version 12.

Results and Discussion

Plant height

The results demonstrated in Table 2 exposed the significant superiority of the treatment K2 over the different treatments, with the maximum plant height recorded at 70.36 cm, in comparison with 54.95 cm in control (K0). with respect to the

Table 1. Some physical and chemical traits of culture medium

Av. P mg Kg^{-1}	Total N %	$CaCO_3$ g Kg^{-1}	Bulk density g cm^{-3}	O.M %	EC ds m^{-1}	pH
2.26	0.072	165.31	1.24	0.53	1.19	7.92
Cl^- Mq L^{-1}	HCO_3^- Mq L^{-1}	CO_3^{2-} Mq L^{-1}	Na^+ Mq L^{-1}	Mg^{2+} Mq L^{-1}	Ca^{2+} Mq L^{-1}	Av. K mg Kg^{-1}
1.86	1.47	Nil	0.68	4.12	5.21	72.48
	Texture		Clay g Kg^{-1}	Silt g Kg^{-1}	Sand g Kg^{-1}	$SO_4^{=}$ Mq L^{-1}
	Sandy clay loam		340.3	85.5	574.2	2.10

Table 2. Effect of potassium, spray schedule and their interaction on plant height (cm)

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	52.73	54.57	57.57	54.95
K1	64.23	69.50	69.00	67.57
K2	68.25	70.59	72.24	70.36
K3	61.37	65.63	67.25	64.75
K4	61.93	64.40	67.59	64.64
Average	61.70	64.93	66.73	
L.S.D 5 %		K = 1.68	S= 1.19	K×S = 2.93

S1: Seedling stage (10 days after transplanting, with four true leaves, S2: Flowering stage (21 days after the first spraying), S3: Fruit-setting stage (42 days after the first spraying), K0: 0 mg L^{-1} (Spraying with deionized water only), K1: K spraying at 1000 mg L^{-1}, K2: K spraying at 2000 mg L^{-1}, K3: K spraying at 3000 mg L^{-1}, K4: K spraying at 4000 mg L^{-1}.

effect of spraying timelines, the S3 treatment resulted in the largest plant height of 66.73 cm, whereas the lowest height was noticed under S1, measuring 61.70 cm. In addition, the interaction between potassium treatments and spraying timelines demonstrated that the treatment K2S3 combination significantly raised plant height, achieving the maximum value of 72.24 cm, in comparison with the lowest height of 52.73 cm noticed in the K0S1 treatment.

Total leaves area

The results in Table 3 showed significant differences among potassium spray treatment. K2 treatment yielded the largest of leaf area, measuring 100.35 dm^2 plant^{-1}, whereas control treatment (K0) recorded the lowest leaf area of 74.48 dm^2 plant^{-1}. Correspondingly, the spraying timelines had a significant effect, with S3 yielding the maximum of leaf area 96.80 dm^2 plant^{-1}, compared to the minimum value of 82.86 dm^2 plant^{-1} in S1 treatment. Furthermore, the interaction between potassium concentrations and spraying timelines significantly affected leaf area, with the K2S3 combination reaching the maximum value of 109.59 dm^2 plant^{-1}, while the treatment K0S1 recorded the lowest value of 74.34 dm^2 plant^{-1}.

Dry weight of the vegetative system

The results in Table 4 showed that foliar potassium treatments had a notable influence on the dry weight of vegetative system. The treatment K4 recorded the maximum value at 126.74 g, while the treatment (K0) showed the minimum value of 75.78 g. Spraying timelines also significantly affected at this trait, with S3 attaining the highest dry weight of 115.22 g in comparison with 93.66 g in plants treated once (S1). Furthermore, the interaction between potassium concentrations and spraying timelines significantly affected this trait, whereas the K4S3 combination creating the highest dry weight of 139.93 g, whereas K0S1 recorded the minimum value at 75.29 g.

Total chlorophyll

The data demonstrated in Table 5 illustrated the significant effect of potassium foliar treatments on the total chlorophyll content in the leaves. The treatment K3 recorded the maximum value at 114.02 mg 100 g^{-1}, in comparison with 78.13 mg 100 g^{-1} in the treatment (K0). Spraying timelines also significantly influenced in chlorophyll content, with treatment S2 achieving the maximum value of 93.24 mg 100 g^{-1}, while S1 noted the lowest value at 90.98 mg 100 g^{-1}. Furthermore, the interaction between potassium concentration and spraying timelines significantly impacted this trait, with the K3S2 combination attaining the highest chlorophyll of 120.20 mg 100 g^{-1}, while the minimum value of 75.01 mg 100 g^{-1} was showed in K0S1.

Flower inflorescences number

The analysis demonstrated in Table 6 showed a significant effect of foliar K treatments on the amount of flower inflorescences in plant. The treatment K4 produced the maximum average number, attaining 19.57 inflorescences plant^{-1}, in comparison with the minimum value of 13.94 inflorescences plant^{-1} showed in the treatment (K0). Spraying timelines also significantly influenced in this trait, with S3 achieving highest value of 17.72 inflorescences plant^{-1}, whereas S1 treatment noted the minimum value at 16.31 inflorescences plant^{-1}. In addition, the interaction between potassium concentrations and spraying timelines significantly affected this trait, with the K4S3 combination providing the highest number of 20.48 inflorescences plant^{-1}, while the minimum number of 13.47 inflorescences plant^{-1} was showed in K0S1.

Table 3. Effect of potassium, spray schedule and their interaction on total leaf area per plant (dm^2 plant^{-1})

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	74.34	74.49	74.61	74.48
K1	87.36	95.64	104.12	95.70
K2	90.48	101.58	109.59	100.35
K3	84.37	94.23	99.85	92.81
K4	77.79	98.15	95.86	90.50
Average	82.86	92.81	96.80	
L.S.D 5 %		K = 1.25	S= 0.88	K×S = 2.16

Table 4. Effect of potassium, spray schedule and their interaction on dry weight of the vegetative system (g)

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	75.29	76.49	75.57	75.78
K1	95.83	105.93	120.39	107.38
K2	84.69	94.45	108.58	95.90
K3	101.64	114.67	131.65	115.98
K4	110.87	129.43	139.93	126.74
Average	93.66	104.194	115.22	
L.S.D 5 %		K= 1.45	S= 1.03	K×S = 2.52

Table 5. Effect of potassium, spray schedule and their interaction in the leaf total chlorophyll content (mg 100 g^{-1})

Concentration of Potassium	Spraying dates			
	S1	S2	S3	Average
K0	75.01	78.5	80.89	78.13
K1	97.23	95.13	99.67	97.34
K2	75.23	79.63	71.78	75.54
K3	108.21	120.20	116.35	114.02
K4	99.23	92.78	94.89	95.63
Average	90.98	93.24	92.71	
L.S.D 5 %		K = 1.12 S= 0.92	K×S = 1.34	

Table 6. Effect of potassium, spray schedule and their interaction on the number of flower inflorescences (inflorescences plant^{-1})

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	13.47	13.97	14.39	13.94
K1	16.23	17.43	18.29	17.31
K2	15.30	16.47	16.36	16.04
K3	17.83	18.70	19.17	18.56
K4	18.73	19.50	20.48	19.57
Average	16.31	17.21	17.72	
L.S.D 5 %		K= 0.76 S= 0.54	K×S = 1.13	

Fruits number

The data presented in Table 7 demonstrate a significant effect of foliar K treatments on the fruits number per plant. The treatment K4 showed the maximum number of fruits, reaching 33.52 fruits per plant, in comparison with 28.54 fruits per plant in the treatment (K0). Spraying timelines also significantly affected this trait, with the S3 treatment resulting in the maximum number of 32.72 fruits per plant, whereas S1 recorded the minimum value of 29.78 fruits per plant. Furthermore, the interaction between potassium concentrations and spraying timelines revealed that the K4S3 treatment reached the maximum fruit number of 35.35 fruits per plant, while the minimum number of 28.38 fruit per plant was showed in K2S1 treatment.

Fruit weight

The results in Table 8 showed a significant effect of foliar potassium treatments on weight of fruit. The treatment K4 revealed the maximum average of fruit weight of 96.58 g, in comparison with the minimum value of 77.93 g revealed in the treatment (K0). Spraying timelines also had a significant impact, with the treatment S3 producing in an average fruit weight of 93.63 g, whereas the treatment S1 revealed the minimum weight of 79.06 g. while, the interaction between potassium concentrations and spraying timelines was significant, with the treatment K4S3 reaching the maximum weight of fruit of 106.12 g, while the minimum weight of 71.96 g was showed in K0S1 treatment.

Plant yield

Data demonstrated in Table 9 reveal the significant superiority of the treatment K4 over the other K treatments, achieving the maximum plant yield of 3.25 kg plant^{-1}, in comparison with the minimum yield of 2.22 kg plant^{-1} showed in the treatment (K0). Spraying timelines also had a significant effect, with the treatment S3 producing the maximum yield of 3.08 kg plant^{-1}, whereas the treatment S1 resulted in the minimum yield of 2.36 kg plant^{-1}. While, the interaction between K treatment and spraying timelines was significant, with the treatment K4S3 outperforming all other treatments by creating the greatest yield of 3.75 kg plant^{-1}, while the minimum yield of 2.05 kg plant^{-1} was showed in K0S1 treatment.

Nitrogen

Analysis demonstrated in Table 10 reveal that there were no significant differences among K foliar treatments or spraying timelines regarding the percentage of nitrogen content in leaf. Nevertheless, the interaction between the study factors was significant, with the treatment K4S2 showing the nevertheless nitrogen concentration of 2.87 %, in comparison with the low minimum est value of 2.12 % showed in K2S2 treatment.

Potassium

The data demonstrated in Table 11 reveal the significant superiority of the treatment K4 over the other K treatments, achieving the maximum leaf K content 2.73 %, in comparison

Table 7. Effect of potassium, spray schedule and their interaction on fruit number (fruit plant^{-1})

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	28.53	28.72	28.38	28.54
K1	30.28	31.45	33.63	31.78
K2	28.38	29.66	31.96	30.00
K3	29.75	32.94	34.32	32.33
K4	31.98	33.25	35.35	33.52
Average	29.78	31.20	32.72	
L.S.D 5 %		K= 0.23 S= 0.16	K×S = 0.40	

Table 8. Effect of potassium, spray schedule and their interaction on fruit weight (g)

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	71.96	77.53	84.32	77.93
K1	75.31	80.61	83.79	79.90
K2	76.74	82.53	89.79	83.02
K3	84.55	91.32	104.14	93.33
K4	86.75	96.88	106.12	96.58
Average	79.06	85.77	93.63	
L.S.D 5 %		K = 1.04 S= 0.74	K×S = 1.81	

Table 9. Effect of potassium, spray schedule and their interaction on plant yield (kg plant^{-1})

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	2.05	2.23	2.39	2.22
K1	2.28	2.54	2.82	2.54
K2	2.18	2.45	2.87	2.50
K3	2.52	3.01	3.57	3.03
K4	2.77	3.22	3.75	3.25
Average	2.36	2.69	3.08	
L.S.D 5 %	K = 0.03	S= 0.02	K×S = 0.06	

Table 10. Effect of potassium, spray schedule and their interaction on the leaf content of nitrogen (%)

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	2.24	2.13	2.18	2.18
K1	2.23	2.24	2.35	2.27
K2	2.23	2.12	2.26	2.20
K3	2.51	2.46	2.68	2.55
K4	3.01	2.87	2.79	2.89
Average	2.44	2.36	2.45	
L.S.D 5 %	K = N.S	S= N.S	K×S = 0.4	

with the minimum concentration of 1.72 % showed in the treatment K0. Spraying timelines also had a significant effect, with the treatment S3 resulting in the maximum value of 2.34 %, whereas the treatment S1 recorded the minimum concentration of 2.03 %. Moreover, the interaction between the study factors was significant, with the treatment K4S3 exhibiting the maximum K level of 2.98 %, while the K0S1 treatment revealed the minimum concentration at 1.68 %.

Discussion

K is an essential macronutrient required for growth of plant and development, playing a fundamental role in a wide extent of biochemical and physiological processes. Sufficient K nutrition enhances photosynthetic improves by effectiveness carboxylase enzymes engaged in the Calvin cycle and controlling stomatal closing and opening, hence improving gas exchange and decreasing water loss. This, in turn, improves the plant's ability to resist stresses conditions (21, 22). furthermore, K improves water absorption from soil and encourages the plant's water retention ability. It also promotes the absorption of other macro and micronutrients, further backing overall growth of plant (23). K shortage has been shown to weaken growth of root, decrease lateral branching and reduce overall growth of vegetative, while adequate K fertilization boosts biomass and root length, hence increasing nutrient absorption performance, consistent with findings noted for tomato plants (24–26). As well, K is essential for chlorophyll synthesis, managing the activity of enzymes involved in chlorophyll creation. It aids the transfer of sugars, amino acids and other precursors to chloroplast, although maintaining stomatal ionic balance and activity within cells, hence stabilizing chlorophyll molecules and decreasing their degradation. This ultimately assists to increased chlorophyll collection and enhanced photosynthetic efficiency.

K also acts a key role in improving both the quantity and quality of agricultural yield. It improves carbohydrate formation and translocation from leaf to storage or generative organs, resulting in increased size of fruit and enhanced sugar, juice and other quality traits (27, 28). In addition, K maintains osmotic evenness and cellular stability, accelerates fruit maturation, increases number of flower and enhances pollination and set of fruit, collectively contributing to higher production and enhanced quality of fruit (29). These findings are corroborated by previous researches on tomato (30–32). The better performance recorded at higher potassium concentrations can be ascribed to the enhanced availability of K through foliar application, allowing fast and direct absorption by the leaf and elevating K content in tissues of plant (33). These results are in agreement with reports on tomato (34), sweet pepper (35) and cucumber (36). It is essential to note that the soil content of nutrients, especially macronutrients, as illustrated in Table 1, promoted upon their absorption by the root to increased accumulation in the plants. This, in turn, had a positive impact on their physiological efficiency, leading to enhanced growth traits of tomato plants, increased yield and improves quantitative traits.

These results not only validate the physiological and biochemical significance of K but also highlight practical effects for industrial and economic durability. By enhancing growth, yield and quality of fruit, foliar K fertilization illustrates a viable strategy for enhances profitability in tomato yield systems. However, further research is needed to assess large-scale practicality, potential combination with amendments like

Table 11. Effect of potassium, spray schedule and their interaction on the content of the leaf of the potassium (%)

Concentration of potassium	Spraying dates			
	S1	S2	S3	Average
K0	1.68	1.72	1.76	1.72
K1	1.89	1.94	2.19	2.00
K2	2.03	2.11	2.34	2.16
K3	2.13	2.33	2.43	2.29
K4	2.45	2.78	2.98	2.73
Average	2.03	2.17	2.34	
L.S.D 5 %	K = 0.15	S= 0.05	K×S = 0.9	

biochar and to address diversity across varied agro-ecological conditions.

Conclusion

The results of the study emphasize the significance of foliar K fertilization in tomato plant for attaining substantial enhancements in vegetative growth and improving both the production and chemical content of fruits. Therefore, it is recommended to apply precise fertilization programs using appropriate K concentrations ranged from 2000 to 4000 mg L^{-1}, as these amounts were found to have a important positive effect on plant height, leaves area, weight of fruit and fruits number of plants, thus increasing the yield. However, the study illustrated that spraying K for three times during the growing season is a critical factor in enhancing plant growth and promoting the chemical content of leaf and fruit. This technique directly contributes to rising the weight of fruits and the overall number of fruits per plant, thereby enhancing the total productivity of the plants. Moreover, it is advised that this fertilization program be enforced under agro-ecological parameters corresponding to those of the research, as it can strengthen nutrient uptake performance and improve photosynthetic activity, assisting plant vigor and rising resilience against different environmental adversity.

It is also recommended to carefully assess the timing of sprays based on diverse plant growth stages. Early foliar application at the true leaf structure stage ensures best nutrient absorption, in contrast spraying during flowering and fruit growth boosts chlorophyll collection and augments quality of fruit. Besides, farmers should attach to technical guidelines with respect to dosage and repetition to prevent excessive K application, which could detrimentally affect the nutrient stability in the plants and soil.

These results not only expose a novel comprehension of the synergistic effects of K level and foliar application timing on tomato physiological and yield traits but besides highlight overlooked multidisciplinary connections between plant feeding, crop management and nature-friendly agriculture practices. The research detects practical potential for enhancing industrial tomato yield performance, decreasing input depletion and improving economic profit for farmers. besides, the results furnish a foundation for future research designed at integrating nutrient betterment with accuracy agriculture technologies, directing both environmental challenges and market needs. By measuring the effects of K foliar application under local agro-ecological parameters, this study offers globally appropriate insights that can inform large-scale cultivation plans, encourage sustainable crop management and promote economic efficiency in the tomato industry.

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Authors' contributions

BMA and IHMSAJ were responsible for creating the initial research idea and collecting the literature review to achieve the final idea for this research, as well as performing statistical analysis after collected data to investigate the effect of individual factors solely or the interaction between them; moreover, a comprehensive reading of the final manuscript. AKA and AFZAD carried out the experiment, data collection and interpretation of results; moreover, the initial writing of the manuscript also compared the findings with the literature and made the conclusions built into the output of this research. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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